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PROCEEDINGS

OF

THE ROYAL IRISH ACADEMY.

1846. No. 54.

## May 25.

REV. HUMPHREY LLOYD, D.D., President, in the Chair.

It was resolved, on the recommendation of Council, that a subscription be opened for the purchase of the *Domnach Airgid*, and that the Academy do subscribe fifty pounds.

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The President resumed and concluded the reading of his paper "On the Variations of the Magnetic Declination."

The observations at stated hours, in the Magnetical Observatory of Dublin, commenced November 1, 1838, the hours of observation being at first limited to the day. In the beginning of the year 1840, the observations were taken *every alternate hour*, night and day, according to the more comprehensive scheme which received the sanction of the Royal Society, and which, under the recommendation of that body, has been followed in more than thirty observing stations scattered over the whole globe. This plan has been in operation at the Dublin Observatory until January 1, 1844, when it was discontinued, four years' observations having been found fully sufficient for the determination of all the phenomena connected with the diurnal movements. The results now laid before the Academy are chiefly those of the four years just mentioned. The observations have since been continued upon a different and reduced scale, and with a view to other classes of phenomena.

The changes which the magnetic declination undergoes, at a given place, may be reduced to three classes, namely, 1. *periodical variations*; 2. *secular variations*, which are either continually progressive, or else return to their former values in long and unknown periods; and 3. *irregular variations*, which observe, apparently, no law. The periodical variations hitherto noticed are those which depend upon the position of the Sun with respect to the horizon, or with respect to the equator, and which, therefore, complete their course in a *day*, or in a *year*. The author commences with the first of these.

### *Diurnal Variation.*

In order to determine the laws of the diurnal changes, the observations of each month are combined separately, and the means of the results corresponding to the same hour taken. The observations having been continued for four successive years, there are thus four groups of mean results for each month, the means of which are then taken. And, finally, the mean values for the separate months are grouped together, so as to obtain the mean *yearly*, as well as the mean *summer* and *winter* course of the variation. The total number of individual observations thus combined exceeds 14,000.

When the mean results at each hour of observation, for the *whole year*, are examined, it is found that the course of the diurnal variation is regulated by the following laws:

1. About 7h. 30m. A.M., the north pole of the magnet begins to move to the *westward*, and, therefore, the declination *increases*. This increase continues until about 1 P.M., when the declination attains its *maximum*.

2. The north pole of the magnet then moves to the *east*,

and the declination *diminishes*, but at a slower rate than it has increased. This diminution continues until about 10 P.M., when the declination is a *maximum*. The whole diurnal *range*, between 1 P.M. and 10 P.M., is about 9.4 minutes.

3. During this increase, and subsequent decrease, the declination twice reaches its *mean* value, as deduced from the results of the entire day. The epochs of the mean declination are 9h. 30m. A.M., and 6h. P.M. nearly.

4. There is a second, but much smaller oscillation of the magnet during the night and morning, the north pole moving slowly to the *west*, from 10 P.M. until 3 A.M., nearly, when there is a second *maximum*, and then returning to the *east* until 7 A.M., when there is a second *minimum*.

When the means corresponding to the several hours of observation, taken for the six summer months, and the six winter months, separately, are examined, it is found that the course of the diurnal variation is very different in the two seasons. The following are the distinguishing circumstances:

1. The range is much greater in summer than in winter. The mean summer range amounts to 12·2 minutes; the mean winter range to 9·0 minutes.

2. In summer, the *morning* minimum is greater than the *evening* minimum, which is not the case in the curve for the entire year; and, consequently, the greatest range is between 7 A.M. and 1 P.M. In winter, on the other hand, the morning minimum, and the small preceding maximum, disappear altogether; and the course of the diurnal change presents only a single oscillation.

If now the inquiry be extended from the *seasons* to the *separate months*, it is found that the course of the diurnal change, in *each* of the six months from April to September inclusive, has all the characters of the mean summer variation, both as respects the *law* of the change and its *amount*. In like manner the diurnal variation, in each of the six winter months, corresponds with the mean variation for the whole period; the nocturnal oscillation vanishing, and the course of the representative curve, from 10 P.M. to 9 A.M., being in all nearly a straight line. Thus the curves for the separate months appear to distribute themselves into two groups, depending upon the position of the sun to the north or south of the equator; and it is remarkable that the transition from one to the other system appears to take place abruptly, and almost *per saltum.*

The whole *range* is nearly the same in each of the six summer months. The *maximum range* occurs in April, and its amount is 13′.3 ; this maximum is followed by a secondary minimum in July, which is succeeded by a secondary maximum in August. There is a sudden change in the magnitude of the range from February to March, and again from October to November. The *minimum* range occurs in December, and its amount is 7′.0.

The physical dependence of the phenomena of the changes of the declination upon the sun is evident from the fact, that they observe a diurnal and an annual period. In addition to this fundamental fact, it has been long ago observed, with respect to the diurnal change, that the time of the maximum of westerly declination follows the sun's meridian passage at a nearly constant interval, and that the morning and evening minima are in like manner connected (although not so closely) with the hours of sunrise and sunset; and another point of connexion between the cause and effect has been established by the fact, long since observed, of the greater magnitude of the range in summer than in winter.

Dr. Lloyd proposes to show that the sun acts by means of its heating power (as, in fact, is assumed both in the hypothesis of Canton and that of Christie); and that the connexion between the changes of declination and those of temperature is more intimate than has been hitherto supposed.

The force which produces the deviation of the magnet from its mean position, at any moment of the day, is measured by the sine of that deviation,—or, since the deviation is small, by the angle of deviation itself, or by the ordinate of the diurnal curve; and the sum of all these forces throughout the day, or the integral of the diurnal action, is measured by the *area of the diurnal curve.* Dr. Lloyd has computed this area for the several months of the year; and, on comparing it with the corresponding area of the diurnal curve of temperature, he finds that there is a marked agreement in the course of the two functions. The slight dissimilarities which exist between them may be accounted for by the circumstance, that it is to the heating power of the sun, exerted upon the *earth's surface*, and not upon its *atmosphere*, that we must ascribe the changes of declination; and the author feels assured, that as soon as we are in possession of data, respecting the diurnal changes of temperature of the earth's surface, sufficient to institute a comparison similar to that now made with the temperature of the air, the agreement of the laws will be found to be still more complete.

### *Annual Variation.*

The annual variation of the declination was discovered by Cassini, in 1786. It appeared from the observations of Cassini, that the north pole of the magnet moved to the *east* during three months, viz., from the vernal equinox to the summer solstice; and, consequently, the declination *diminished.* During the remaining nine months, viz., from the summer solstice to the vernal equinox, it moved to the *west*, and the declination *increased.* The increase, during the nine months, preponderated over the decrease, which took place during the remaining three; and thus the declination was greater at the close of the year than at the commencement. This excess is the yearly amount of the *secular* change, which was then *additive.*

Although the law of the annual variation may be traced in the subsequent observations of Gilpin and Bowditch, it has, nevertheless, escaped the attention of more recent observers. There is but a faint indication of its existence in the Gottingen observations, which were made at the hours of 8 A. M. and 1 P.M.; and Professor Gauss finds, in the mean results deduced from these hours, no "important fluctuation dependent on season." A similar negative result is deduced by Dr. Lamont from the Munich observations, which were made twelve times in the day.

It will be easily understood, that the determination of the annual variation is much more difficult than that of the diurnal change; both on account of the much smaller frequency of the period itself, and the difficulty of preserving the instrument in the same unchanged condition during the much longer time, or of determining and allowing for its changes when they do occur. The Dublin observations appear to possess a peculiar value for this determination. Since the spring of 1841, the magnet of the declinometer has remained absolutely *untouched;* and the suspension thread (which elsewhere has frequently broken) has continued perfect since the instrument was first mounted.

The course of the annual variation in Dublin, as deduced from the results of the years 1841–4, is as follows:

1. During the first three months of the year, the mean daily declination is *nearly constant.*

2. In the month of April the declination begins to *increase;* and it continues to increase until the beginning of August, when it attains its *maximum.*

3. From the beginning of August it *decreases;* and the decrease continues, with rapidity, until the end of the year, when the declination is about five minutes less than at the commencement.

4. The *increase,* from the beginning of April to the beginning of August, is four minutes. The *decrease,* from the beginning of August to the beginning of January, is nine mi-

nutes; thus leaving a total decrease, from year to year, of five minutes.

When we compare the course of these changes with those observed by Cassini, we find that the directions of the movements are precisely opposite,—as, indeed, we might have been led *a priori* to expect from the opposition in the directions of the secular changes; and we are led to generalize the law as follows:

"From the beginning of the year to the beginning or middle of April, the mean declination undergoes little or no change. Thence, to the beginning of August, its movement is *retrograde* (or opposite in direction to the secular change); and from the beginning of August to the end of the year, it is *direct*."

The phenomena just described are, it is manifest, the resultants of two distinct changes, namely, the *annual variation* properly so called, and the *progressive* or *secular change*. If the latter be subtracted, at the rate of 5.′0 per annum, or 0.′4 per month, the remaining numbers give the true annual period. When thus considered, the annual variation exhibits an *increase* of the declination during the first *seven months* of the year, and a *decrease* during the remaining *five months*; the apparently stationary condition of the declination, during the first three months, arising from the mutual compensation of the *periodical* and the *progressive* changes.

It appears, then, that the annual variation (unlike the diurnal in this respect) is a *single* oscillation. The *minimum* occurs near the end of January, and the *maximum* in the beginning of August; and the whole *range* of the change is 6.6 minutes.

The laws of the *annual variations* of the declination and of the temperature, present the most complete accordance in the epochs of *maxima* and *minima*, as well as those of the *mean* values. The maximum of temperature occurs about August 1,—that of declination about August 8. The minimum of temperature takes place about January 15,—the minimum of declination about January 25. Finally, the annual curve of temperature crosses the axis of abscissæ in two points, which correspond to May 1, and October 10,—the corresponding epochs in the curve of declination are May 10, and October 15.

### *Secular Variation.*

The westerly declination is at present *diminishing* from year to year in these countries, and has been so since the year 1818, which was the time of the maximum. The present rate of the secular decrease in Dublin, as deduced from four years' observations, is 5.0 minutes annually.

With respect to the physical cause of the secular change, Dr. Lloyd said that he had been led to form an opinion very different from any of those heretofore held. From the remarkable relation which had been shown to exist between the annual and the secular changes, he was driven to conclude that they depended (ultimately at least) upon a common cause; and that thus the sun was the cause of the *secular*, no less than of the *periodical* changes, although not only the magnitude, but even the direction of the effect were different in different times.

### *Disturbances.*

Having examined the *periodical* and the *secular* variations of the declination, as deduced from the observations made at the Dublin Observatory, it now remains to consider those which, from our ignorance of their laws, we have been accustomed to call "*irregular.*"

Professor Kreil seems to have been the first to notify the remarkable fact, that magnetic *disturbances* occur more frequently at certain hours than at others; and, that the *direction*, as well as the *frequency*, of these movements, has a dependence upon the time of the day. Colonel Sabine has since made a more complete and elaborate examination of this question, in his able discussion of the Toronto observations, and has arrived at conclusions for the most part confirmatory of those obtained by Professor Kreil.

In these investigations, however, those disturbances only are taken into account which exceed a certain arbitrary limit; and, even of these, the *frequency* is considered without any reference to their *magnitude.* In examining the question of the periodicity of disturbances, Dr. Lloyd has thought it necessary to pursue a different course. His method consists in taking the differences between each individual result, and the monthly mean corresponding to the same hour, and combining these differences in the same manner as the errors of observation (to which they are analogous) are combined in the calculus of probabilities. The square root of the mean of the squares of these differences is, in fact, a quantity analogous to the *mean error,* and which he therefore proposes to call the *mean disturbance;* and it is evident that its values, at the several hours of the day, and at the several seasons of the year, are measures of the *probable* disturbance to be expected at the corresponding times.

The values of this function have been deduced for the several hours of observation, in each month of the year 1843; and those for the entire year are obtained from them by a repetition of the same process. These numbers show that the mean disturbance follows a law of remarkable regularity in dependence upon the hour. During the day, i. e. from 6 A.M. to 6 P.M., it is *nearly constant;* at 6 P.M. it begins to *increase,* and arrives at a *maximum* a little after 10 P.M.: it then decreases with the same regularity, and arrives at its constant day-value about 6 A.M.

The preceding results are independent of the direction of the disturbance. If, however, we take the sum of the squares of the easterly and westerly deviations separately, we find that the *easterly* disturbances preponderate during the night, and the *westerly* during the day; the former being, however, much more considerable than the latter, and the difference reaching a maximum about 10 P. M.

It thus appears that the mean daily disturbance observes a regular period, both in magnitude and direction; and this period, it is worthy of remark, is precisely the reverse of that of the regular diurnal movement,—the *mean position* of the magnet being nearly constant during the *night*, the *mean disturbance* during the *day*;—the principal oscillation of the magnet, in the *regular* movement, being to the *west* during the *day*, while that of the *irregular* movement is to the *east* during the *night*. From these remarkable relations it seems evident that the two classes of phenomena are physically connected; and Dr. Lloyd is led to regard the disturbance which prevails about 10 P.M., as an *irregular reaction* from the regular day movement, and dependent upon it both for its periodical character and for its amount.

If this hypothesis be a just one, it will, of course, follow that the magnitude of the mean disturbance will vary, in some direct proportion to the daily range, and should, therefore, be greater in summer than in winter. This (which is contrary to the results deduced by Professor Kreil and Colonel Sabine, with reference to the *frequency* of disturbances exceeding a certain limit) appears to be the fact. The mean disturbance, deduced from the observations of 1843, is, for the summer six months, 2′.9, and for the winter 2′.2; so that it observes an *annual* as well as a *diurnal* period.

It by no means necessarily follows, from the results now stated, that *all* disturbances have a periodical character. There probably are *two classes* of disturbances, the results of distinct physical causes, of which one observes a period, while the other is wholly irregular; and it is manifest that, in such a case, the period of the former will necessarily be impressed upon the *resultant* mean disturbance. Dr. Lloyd stated that he had instituted, during the last year, a series of observations at short intervals, which seem to afford the means of testing this hypothesis, and of distinguishing the two classes of disturbances, if they really co-exist. The inspection of these observations has nearly satisfied him of the truth of this view; and he believes that it will be found, upon a more minute examination, that there are *two classes of disturbances*, one *periodical and local*, the other *irregular and universal*. Of the former, the principal (if not the only one) is that which occurs about 10 P. M., and which causes the north pole of the magnet to deviate to the east. The magnitude of this disturbance is on the average 10′.0; and its mean duration is an hour and a half. The epoch of the maximum of easterly deflection varies from 7½ P. M., to 1½ A. M., the mean epoch being a few minutes before 10 P.M.; and, hence, it is evident, that its effect on the monthly mean curve is to produce a general increase of the negative ordinate between these limits of time, as well as the minimum which occurs at 10 P. M.

It seems to follow also, from these facts, that the ordinary mode of grouping the observations, by taking the mean of all the results at the same hour,—although it truly gives the *mean* diurnal curve for the period embraced by the observations,—does not represent the actual course of the movement during any one day. In order to obtain the *representative*, or *type* curve, as it may be called, it seems necessary to combine the results in a different manner, of which the author hopes to speak more fully upon a future occasion.

Mr. Ball exhibited a specimen of Apteryx Australis, recently purchased for the University Museum, and made some observations on the species, referring to the elaborate papers of Yarrell and Owen in the Transactions of the Zoological Society of London. He noticed the adaptation of the position of the nostrils of the bird to its wants; being placed at the end of the bill, it is enabled, by its powerful olfactory apparatus, to detect the burrowing larvæ on which it feeds. This is accomplished by snipes, woodcocks, &c., by means of ex-